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Critter-Copter

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Abstract

The goal of this project is to aid marine biologists in their search for whales to tag and study. This is achieved by creating an audio subsystem on a quadcopter in order to extend the biologists' search range. This audio subsystem will wirelessly transmit audio from the drone's search area back to the boat. Assuming the drone already has a camera, this payload will effectively extend the hearing and sight capabilities of the researchers on the boat.

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Introduction & Background

Studying whales is difficult due to the challenges of observing the mammals in their natural habit. As late as the 1990's, marine biologists knew very little about the behavior of many whales due to a lack of technology enabling underwater observation. Once a whale submerges to a certain depth, it is nearly invisible from above, making it hard to track and observe (Halpin). To help solve this problem, DTAG, a digital acoustic recording device, was invented to gather data on whales below the surface of the ocean. DTAG, along with other advances in whale tagging technology has allowed researchers to acquire much more data on whale behavior. The DTAG is attached to a whale's back with a suction cup that typically stays attached for about a day. This allows researchers to gather data on the movement, orientation, and depth of the whale (Tyack).

The invention of DTAG was a breakthrough in whale research, however, the continued challenge lies in actually finding the whales and landing the tag on the whale's back. Researchers aboard small boats, typically less than 20 feet in length, head out to sea in search of whale pods. Because the researchers are already so close to the water's surface, it is difficult for researchers to locate the whales unless they surface nearby. It is common for researchers to locate a whale's general direction by the sound of its breach, or exhale from the blowhole.

This project was partially inspired by Greg Marshall of National Geographic. On a shark research project, Greg realized that study of animals' natural behavior would be much improved if he could put a video recorder on the animal. A few years later he helped develop the Crittercam. The Crittercam is capable of collecting various types of data such as depth, temperature, and acceleration (National Geographic). This cam allows biologists to study the animals in their natural habitats without disturbing them with human observation. The cam has already helped biologists study the foraging habitat of the endangered Hawaiian monk seal. The Crittercam continues to be redesigned so that it becomes smaller and enables more features for research. This will allow the cam to be placed on smaller animals. The Crittercam has redefined animal research and will continue to aid biologists.

Our team's projected goal is to aid in this process as well. Our team seeks to aid researchers attempting to find and tag whales. The project will accomplish this by creating an audio subsystem on a quadcopter in order to extend the biologists' search range. This audio subsystem will consist of microphones that will wirelessly relay audio from the drone's search area back to the boat. This was done with the assumption that the copter already has a camera. This payload will allow researchers to listen for whales off in the distance. It will essentially extend the hearing and sight capabilities of the researchers on the boat.

Many quadcopters come equipped with cameras that have the ability to live stream video to whoever is controlling the quadcopter. This project assumes this feature is available, and that any features implemented will add value to an existing drone with live video streaming capabilities. Our addition of the microphones will allow researchers to not only use the camera to spot whales, but to also listen for whales so that the quadcopter operator can adjust his flight pattern upon hearing a whale's blow.

Goals

The first base-line goal for this project is to add one omni-directional microphone to the quadcopter. The audio signal will then be streamed live to the boat, where the researchers can actively listen for whale noises breaching the ocean's surface.

In addition to the audio signal, the second base-line objective of the project was to add a GPS positioning system. This system would be able to communicate location, through serial data, between the copter and it's controller on the boat. This will serve two purposes: to avoid losing the quadcopter over the ocean, and ease directing the boat to animals spotted or heard by the copter. In order to do this, the group will need to purchase a copter and modify the existing frame to create space for the desired acoustic and GPS tracking system payloads. This goal was established at the start of the project. However, upon further research as the project continued, we found that many drones already have a GPS component to them. Our team decided that it would be more beneficial to focus our time and resources on implementing the audio subsystem instead.

The reach goal for this project is to be able to set up a sound localization system using multiple uni-directional microphones. In this system, the drone would have four microphones, each pointed in a different cardinal direction. This would create four overlapping areas. Then if two microphones receive the audio signal first, the copter would send a signal indicating the direction of the noise back to the boat, and the operator would have a better sense of which direction it came from. The logistics for this goal still need to be thoroughly tested.

Design

System Design Overview

The block diagram for the system design can be seen below.

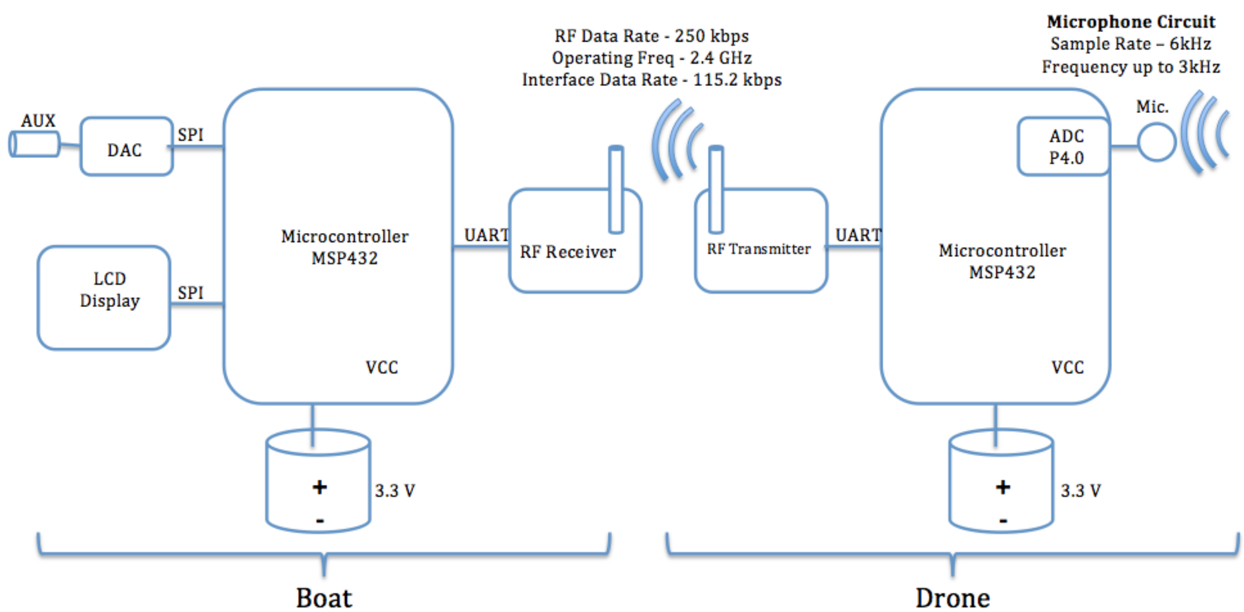

Figure 1: System Block Diagram

As can be seen in Figure 1, the remote audio system has two main components: the receiving end on the left, which will remain on the boat, and the transmitting end on the right, which will be attached to the drone.

We found that most of the whale's blow noise lies below 1.5 kHz. A set of spectrograms for whale blow recordings obtained from the Internet revealed this (refer to the Methodology section). To be safe, we wanted our microphones to cover frequencies up to 3 kHz. It is good practice to sample at twice the audible range of the signal being sampled, thus the microphone is set to sample at 6 kHz.

Below is a step-by-step overview system operations:

1. Prior to sampling, the analog signal is sent through a low-pass filter with a cut-off frequency at 3kHz to filter out unwanted high frequencies.
2. From the low-pass filter, the analog signal is sent to the ADC
3. The ADC converts the analog signal from the microphone into a digital signal that be transmitted back to the boat
4. The MSP432 sends each sample over UART to the XBee transmitter
5. The XBee receiver on the boat waits for incoming signals from the XBee transmitter on the drone
6. The received digital signal is sent to a D/A Converter, and from there sent to the auxiliary port where a biologist can plug in headphones and listen for whales.

Microcontrollers

The MSP432P401R LaunchPad ($13.00) was chosen for both the boat-receiving end and the drone-transmitting end. It has an ARM Cortex M4F that operates at 48MHz.

Figure 2: MSP432P401R LaunchPad

We initially planned on using the MSP-EXP430F5529LP on the drone, but decided to use MSP432P401R on both ends. They are nearly the same in price and size, while the MSP432 offers much more processing power. The MSP432 supports floating point and offers a 14-bit 1MSPS differential SAR ADC on board, which will be able to easily handle the audio sampling at 6kHz. This model was also chosen because it offers 64KB of RAM, much more than the MSP430, and plenty to support future sensor additions. We originally intended to use Code Composer Studio, with which this board is compatible. However, in the end we ended up using a development environment called Energia (see Methodology).

GPS

One problem the team came across was how the researchers were going to know where the drone was, to find the whales. If the copter goes out of view the researchers need the exact location of it. So the team discussed two ideas for tracking the copter. First, the team researched an RF tracking system. This method uses received signal strength of a certain frequency to find the copter. RF tracking was ruled out because that would involve making an antenna that would manually be used on the boat. Basically a person would have to wave the antenna in all directions until they picked up a signal. The team believes this would be too bothersome and that GPS is more accurate and efficient. In the initial design for the GPS system, there was going to be a GPS receiver on the drone and connect that directly to the microcontroller via UART. The GPS sends NEMA strings, which are ASCI characters that make up a string giving longitude, latitude, date and time. This would be sent through the ZigBee transmitter and would update the LCD screen every second. This way the researchers know exactly where the drone is at all times. Now the GP-735T was chosen for several reasons. Figure 5 shows a trade table of our two options.

GPS Receiver		
Options	GP-735T	Venus GPS
Channels	56	20
Antenna	Internal	None - External
Connector	6 Pin Easy Connect	None
Tracking Sensitivity	-161 dBm	-165 dBm
Cold Start	27 Seconds	29 Second
Price	$31.96	$49.95

Figure 3: GPS Trade Table

The GP-735T has 56 channels compared to the Venus's 20. With more channels, the GPS can process more frequencies per second, which leads to a faster first location fix. The GP also has an internal antenna built into the receiver. This is key for the application because it is weight sensitive and the less parts on the payload the better. The GP also has a 6 pin easy connection, which connects to the microcontroller very easily making it more convenient. Lastly, the GP is more cost effective for the budget.

Figure 4: GP-735T

Subsequent additional research on quadcopters revealed that most high end copters already possess GPS systems. As stated earlier, our team decided that it would be more beneficial to focus our time and resources on implementing the audio subsystem instead of implementing a separate GPS capability as part of our payload.

Microphone, LCD Display, and DAC

We originally intended to use the CME-1538 Omni-directional microphone. This microphone was chosen because it is waterproof and durable while only being .36 grams. However, we were able to purchase a premade microphone amplifier circuit that allowed us to expedite our development process. This new microphone amplifier circuit is the Electret Microphone Amplifier - MAX4466 with Adjustable Gain. This component is the size of a quarter, weighs about a gram and still has a gain of x125.

The weight is very important for our application because it will be on the drone itself, which is not capable of carrying a heavy payload. 3DR's Iris drone for example, which was used for part of our testing, is capable of handling a payload capacity of 400 grams. We found that various other drones have a payload capacity in this range as well, and designed our payload accordingly.

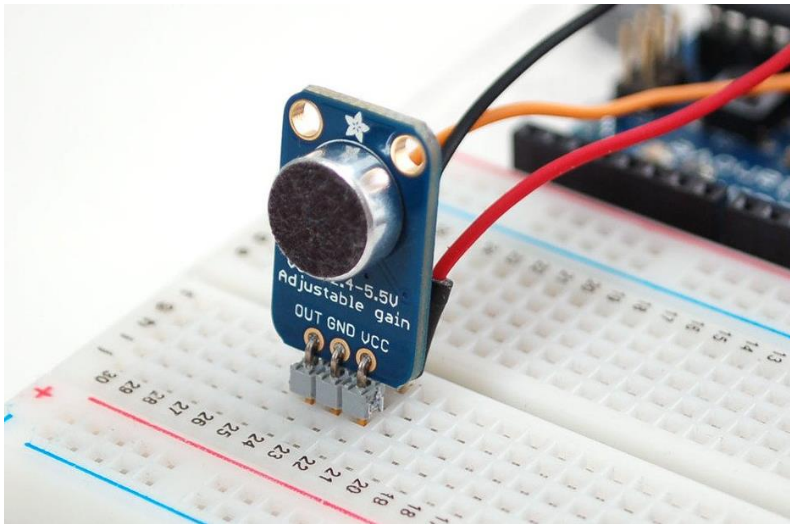

Figure 5: Max4466 Mic/amp

The LCD display chosen, the Sharp LCD Boosterpack (430BOOST-SHARP96), was designed to work with TI microcontrollers, including the MSP432P401R. The default LCD add-on was perfect for the application because it only needs to display the longitude and latitude of the drone (supplied by the GPS). The LCD display is 1.3” and 96 x 96 pixels.

Figure 6: SHARP96 LCD Display

The Digital to Analog Converter (DAC) is necessary for the receiver on the boat, which must convert the received digital signal to analog before passing it to the auxiliary port. We chose the LTC1658 chip, which costs $10.30. This is a 14-bit DAC, which should work well for this application as it operates at a range of 2.7-5.5 Volts and is currently the smallest 14-bit DAC system available (Linear Technology). This is ideal as the group wanted to keep both the payload and the boat device small enough to fit on the quadcopter and in the small skiff, respectively.

Figure 7: LTC1658 DAC

Wireless Connectivity: RF Modules

There are many types of RF modules, but in terms of ease to program, Zigbee technology is a very well known option. Zigbee can be easily manipulated for a wide range of applications, including the purpose of this project. Digi is the company that manufactures products using this Zigbee technology under the technology line of XBee. The 802.15.4 model (Digi) was chosen because it adheres to the IEE 902.15.4 standard for personal area networks. This model type comes in a standard and a pro version, the only difference being the range at which they can communicate.

The XBee-Pro design was chosen for its extensive range, which is necessary for line of sight searching on the water. The device that will attach to the drone will weigh in at 3 grams, a minimal addition to the payload. The XBee-pro has an RF data rate of 250 Kbps, which sends serial data between the two partner devices. This will be able to handle the current transfer rate needed for the audio transmission.

Figure 8: XBee-Pro Audio Transmitter/Receiver

Budget

The project budget is outlined in the table below. All of the parts total in at $240.57. This does not include the enclosure or the drone. Our development and testing process took much longer than expected, so unfortunately we did not get to design an enclosure for our payload. Additionally, we were hoping to get a drone donated to us for testing, but we were unable to bring this to fruition. Without funding or sponsorship we are proud of what we were able to accomplish in such a short amount of time.

Product	Quantity	Total Price
XBee	2 XBees, 1 programming board	74.00
Aux connector	2 connectors	13.04
Microphone and microphone circuit	2 components	17.31
Sharp96 LCD Screen	1 component	19.99
DAC	1 component	19.68
MSP432	2 microcontrollers	49.98
GPS and jumper	2 components	45.58
Batteries	4 batteries	0.99
		Total: $ 240.57

Figure 9: Budget

Methodology

The project's goal was to assist whale researchers in the tracking and tagging of whales. The proposed solution to this issue was to use a quadcopter to listen as well as look for the whales from above so they can be located remotely from a small boat.

The best option for the group was to spend its resources on creating a high-end payload that can be attached to multiple brands of quadcopters. By eliminating the need to buy a copter, we were able to spend our funds on components and testing.

Spectrograms

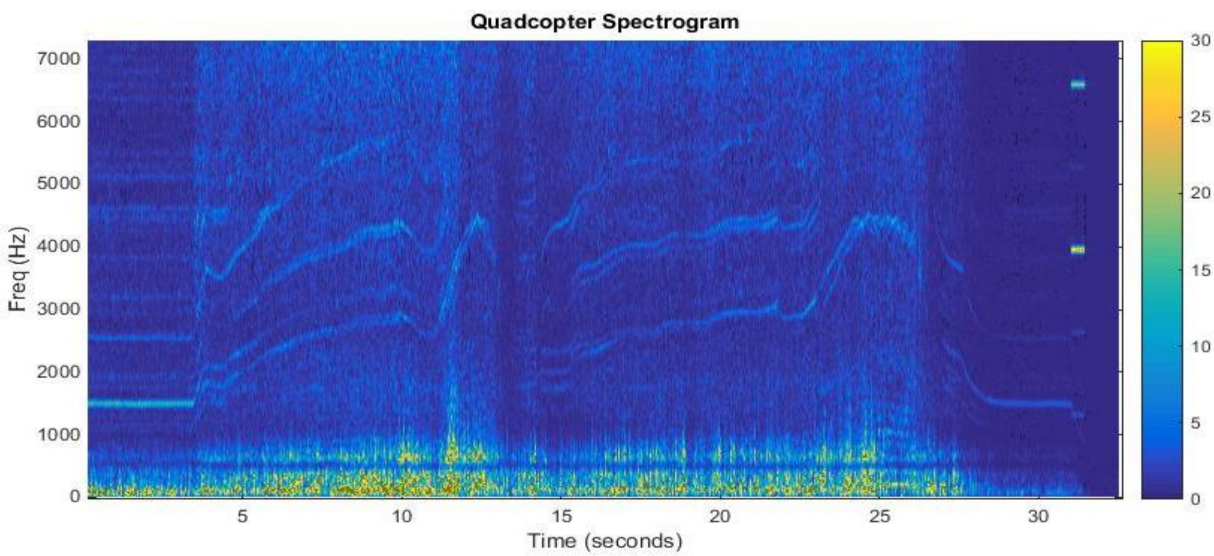

Figure 10: Quadcopter Spectrogram

The spectrogram above is for a 3DR Iris quadcopter. Notice the light blue line at 1.5 kHz from 0 to ~4 seconds, this line is prior to the drone's take off. The wavy light blue lines between 1.5 and 5 kHz represent the frequency resonating from the drone's propellers. The two nearly identical lines that are above our drone's frequency are just harmonics. The more intense yellow and greenish signal below 1 kHz we suspect to be noise from the drone's motor. We were looking to reduce the received level this noise with our payload casing and acoustic baffling.

The largest piece of information gained from this spectrogram is the fact that much of the drone’s propulsion noise is at a frequency above 1.5 kHz. Looking at the spectrograms for whale blows, it can be seen that most of the energy of the blows falls below 1.5 kHz. Unfortunately, most available sounds available online do not specify which species of whale is being recorded.

Knowing that the drone operates above 1.5 kHz and the sound we are looking to sample falls below, this an appropriate cut off frequency for a low pass filter. This low pass filter is placed between the microphone and the ADC, so that it gets filter prior to being transmitted back to the boat.

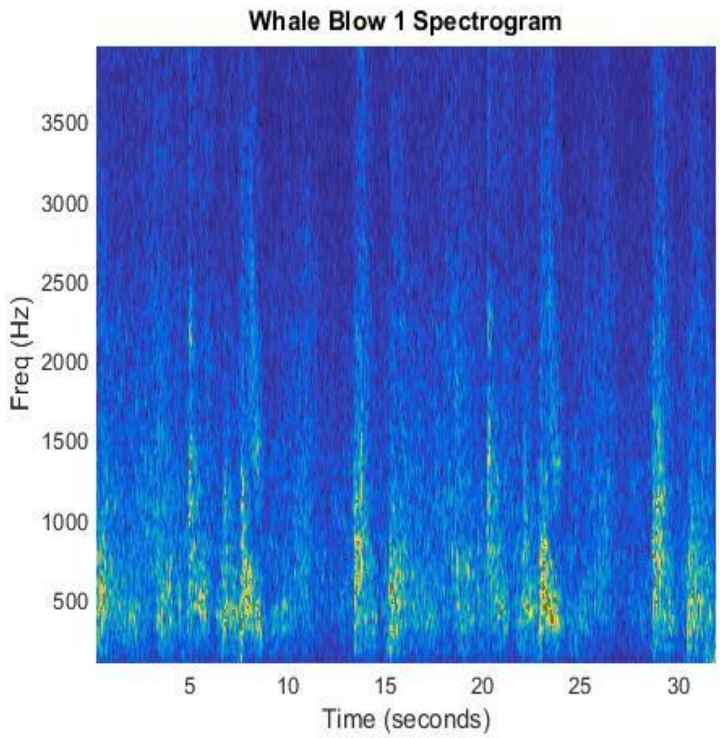

Figure 11: Whale Blow 1 Spectrogram – Raw Recording, unknown species

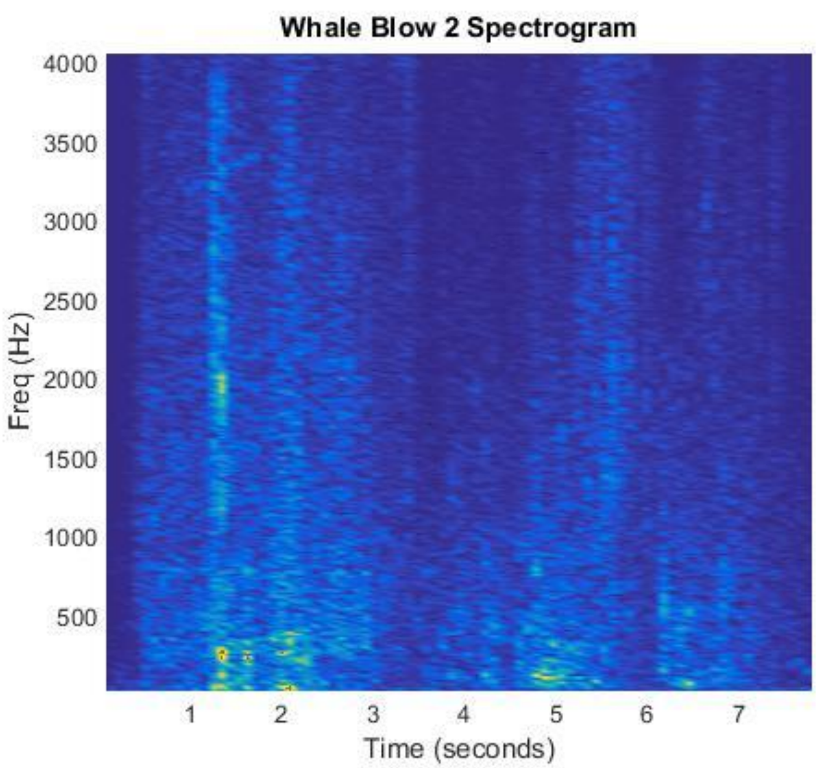

Figure 12: Whale Blow 2 Spectrogram – Raw Recording, unknown species

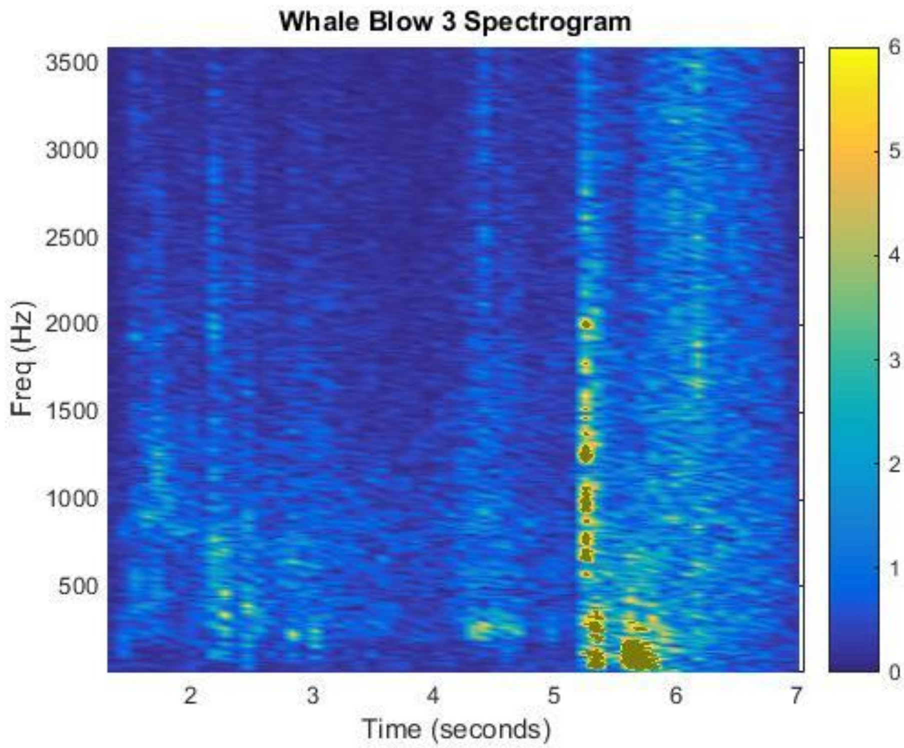

Figure 13: Whale Blow 3 Spectrogram – Raw Recording, unknown species

Building and Testing Microphone Circuit & Anti-Aliasing Filter

The microphone was used to hear the whale blows and the splashing from the whale mucus. The quadcopter is expected to be several meters away from the whales, so the microphone must be amplified.

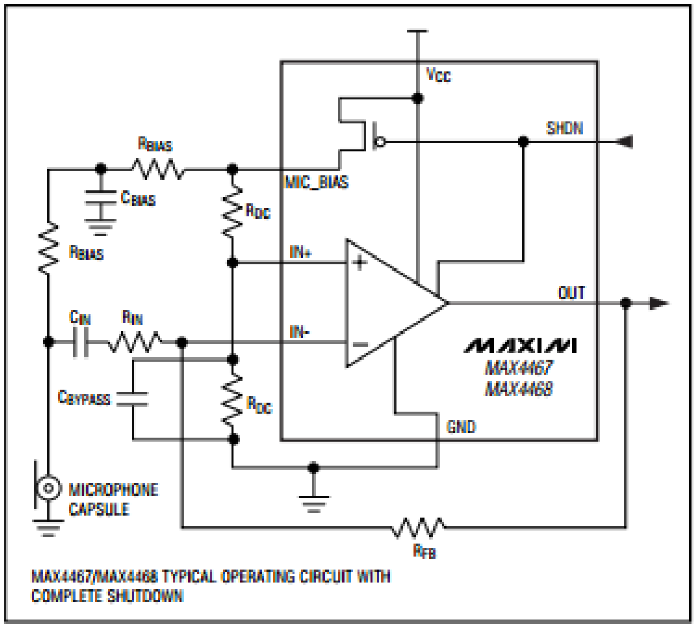

Figure 14: Amplifier circuit

The anti-alias filter we are using is the Max 7405 (Maxim). This filter is an 8th order lowpass with a sharp cut off frequency at 3kHz. The figure below shows the operating circuit we are using for the filter. This filter can be set up with an external clock or it can be configured to use its own internal clock. Although this filter is created for higher quality audio applications, it will be able to handle all audio demands of this payload system.

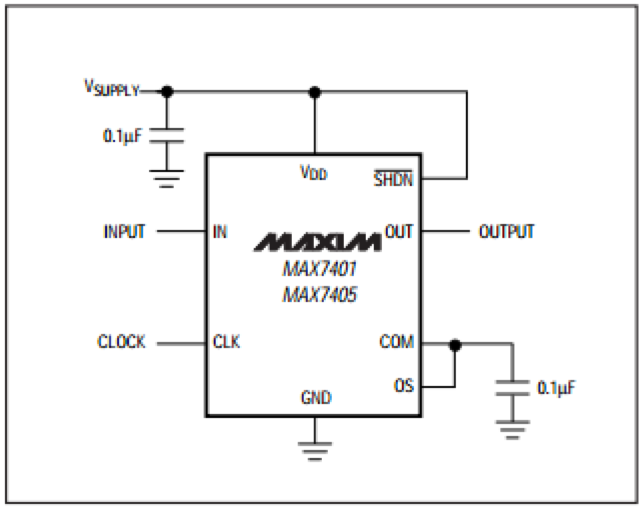

Figure 15: Anti-alias circuit

This filter works by putting a clock frequency of 300KHz into the clock pin. This is because the cutoff frequency for this filter is given by CLOCK/100 = Freq(cutoff). The filtered signal is then sent to the ADC on the MSP432.

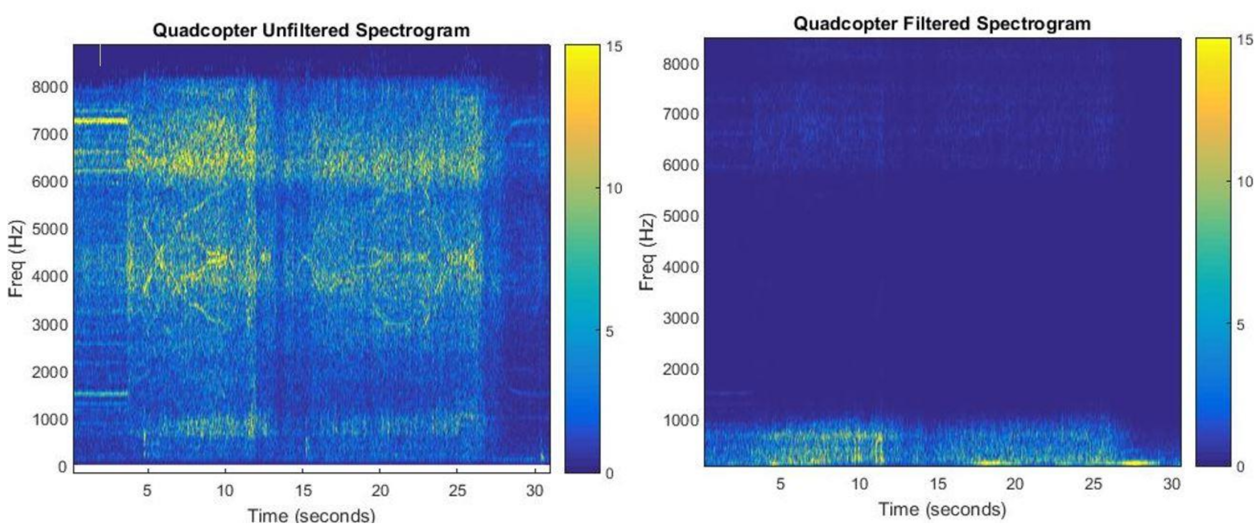

Figure 16: Quadcopter Filter Testing

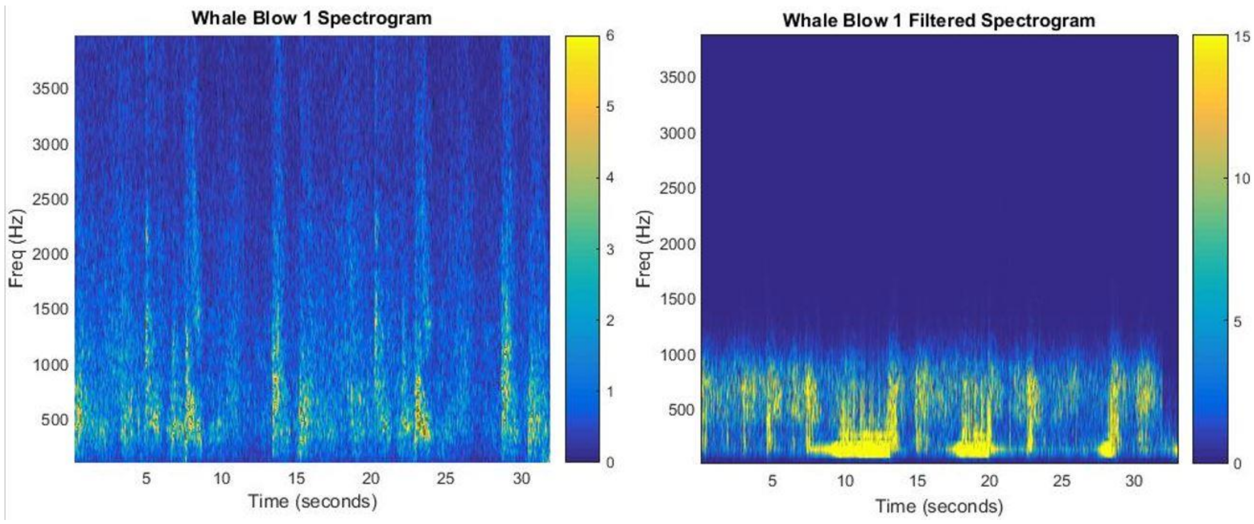

Figure 17: Whale Blow 1 Filter Testing

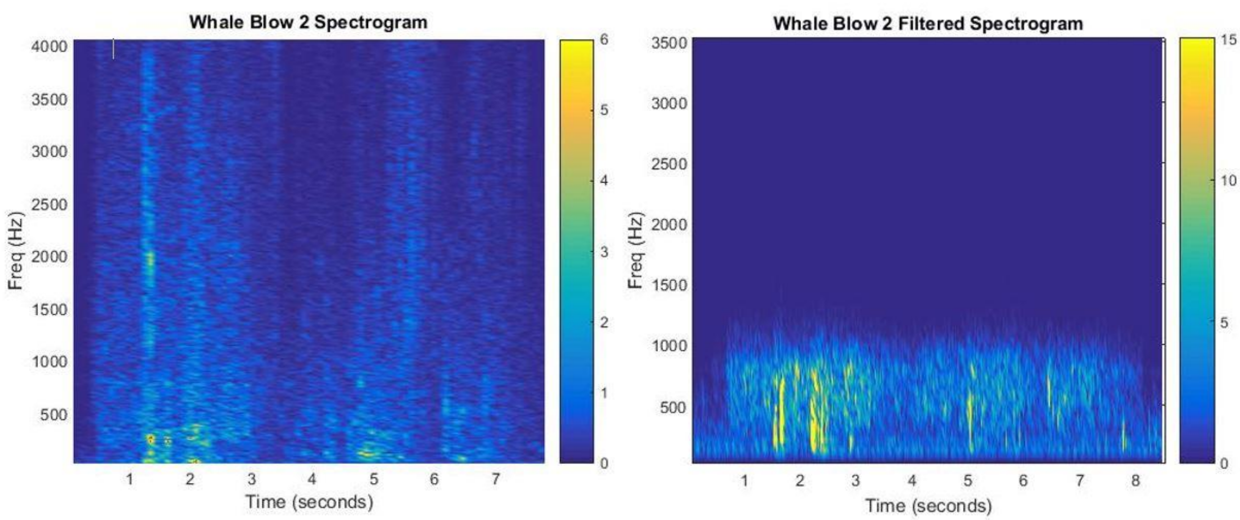

Figure 18: Whale Blow 2 Filter Testing

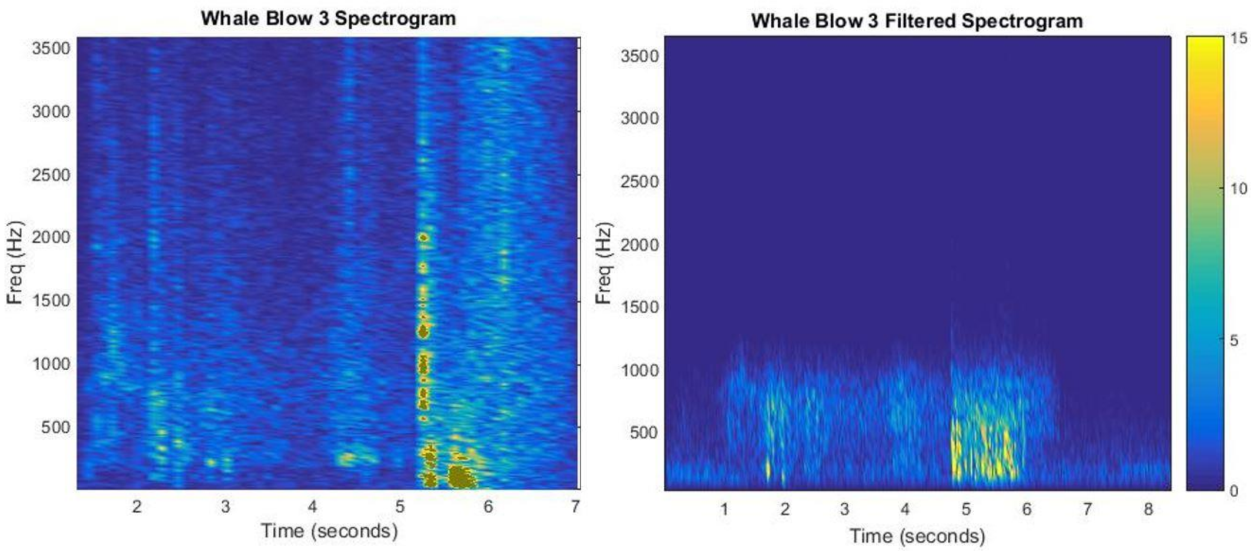

Figure 19: Whale Blow 3 Filter Testing

Configuring and Testing XBee Devices

The first step of configuring the XBee devices was to get them working on a board hooked up to a computer. This involved plugging them into a breakout board that had a mini-USB port. When connected to a computer, both the software and the driver were downloaded. The software, XCTU, is not the most intuitive program as its interface is a series of buttons with unrelated pictures that make it difficult to first navigate around. The driver allowed for the XBees to be seen when connected to the computer through the USB port. Once using the software, the XBees were both tested to be sure the computer could read them. Then, both were connected to the same computer and testing was conducted to see if they initially transmit and receive with each other. This was an easy success, however; they were transmitting over the same default channel that every XBee transmits on. This called for creating a unique network so that these XBees were only talking to each other, in case there is any other device using a similar network when the Critter Copter is in use. In order to create this unique network, the network address was set to a random hexadecimal number to decrease the chances of any other communications signals being on the same channel.

There are two addresses the XBees use to transmit and receive with each other. One is a low and one is a high (my and destination addresses) address. When both addresses oppositely match up with each other, both XBees both can transmit and receive. When only one address matches up, then one XBee is set to transmitting and one is set to receiving. For this application, both XBees will be constantly sending data back and forth as the boat XBee will be sending directions to the drone XBee and the drone XBee will be sending back audio feedback, in the form of serial data. This is shown in the figure below.

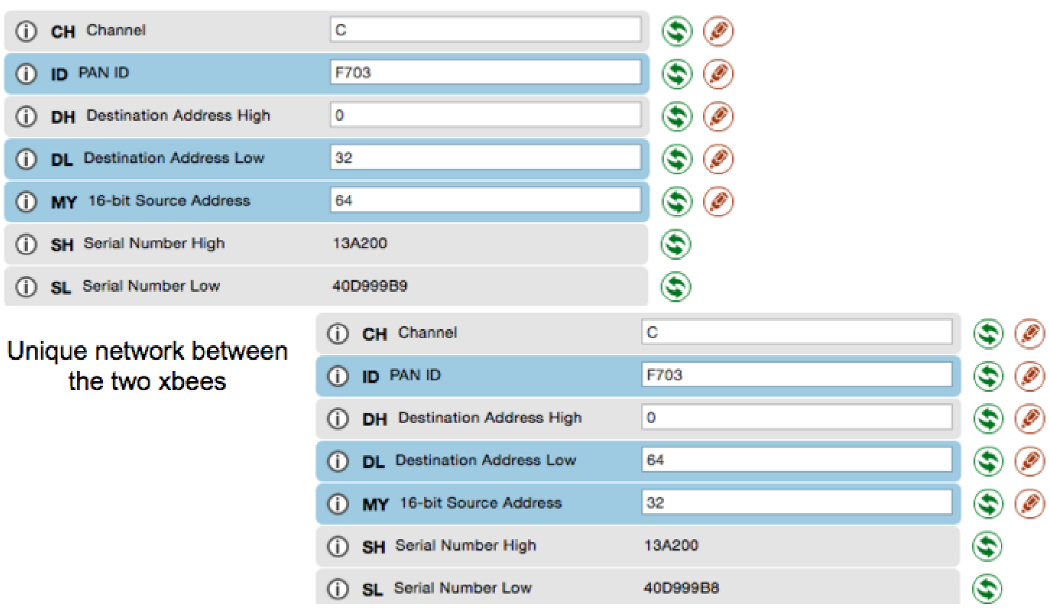

Figure 20: XBees communicating through a unique network

The next step of testing this communication network was to hook them up to different computers, in this case a computer and a laptop. When the laptop XBee moved around the building, transmitting different messages, the computer XBee received all but one message. This lost message is due to the building in which was being used is a dead zone for most networks.

This system has yet to be tested outside, but is expected to operate better than indoors and the network clearance is better and the range is longer.

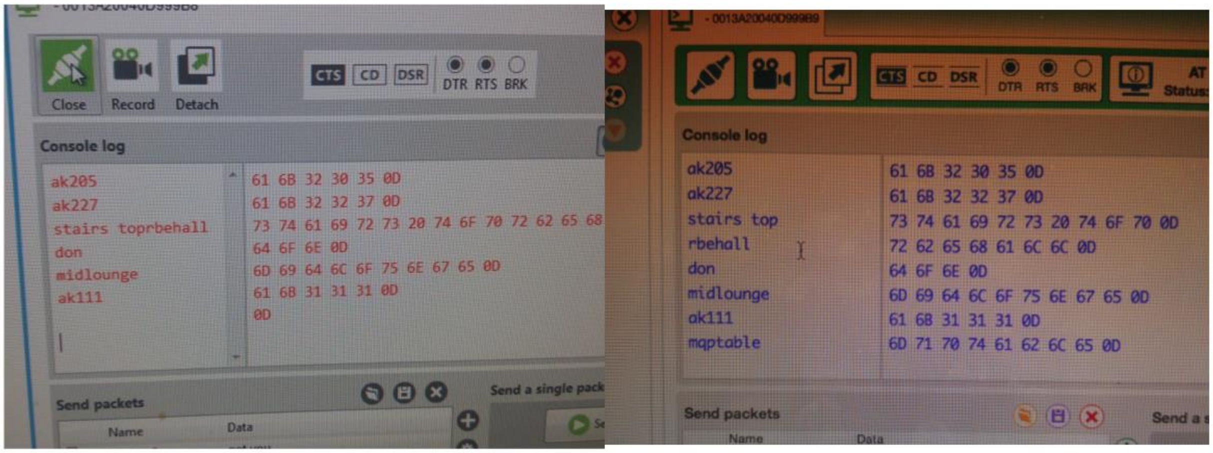

Figure 21: Receiving and Transmitting using XBee software, respectfully

Progressing to use the MSP432 boards, the XBees were tested both receiving and transmitting information to each other while being powered with the use of the function generator and a battery pack, rather than relying on the power from the computer. The XBees and MSP432 are integrated with each other through UART configuration, accomplished using Code Composer Studio, and an Energia sketch. This testing was successful, proving the XBees to be fully functional and integrated into the system.

Unfortunately, throughout the project, the lab flooded and some components were lost, the XBees being one of them. When the XBees were repurchased, they needed to be reconfigured and tested and integrated. This added quite a bit of time to our outlined timeline and contributed to some of our further goals not being achieved.

Configuring and Testing Microcontroller

We started configuring the microcontrollers using Code Composer Studio, but then later switched to a development environment called Energia. Energia abstracts away a lot of things that need to be manually configured in Code Composer Studio, making it easier to do rapid development and testing.

Code Composer Studio Development:

We had successfully configured the microcontroller to take Single Channel Single Sample reading from Port 4 Pin 0 (P4.0). The team had decided to use source code provided by MSPware, which offers various convenient functions for configuring the ADC.

In order to test the microcontroller and ADC configuration so far, we attached P4.0 to a lab bench DC power supply. In order to verify that the ADC was working correctly, we output the converted reading to the LCD display, and were able to assert that the ADC was correctly configured.

After successfully sampling a static voltage from a power supply, we tested the microphone circuit as input to the microcontroller. By attaching the output of the microphone to P4.0 on the microcontroller, we were able to see in code composer that the ADC was successfully sampling sound through the microphone. At this point all we just needed to transmit the sampled signal over XBee.

We configured the microcontroller to communicate with the XBees over UART. The pin connections between the XBee and MSP432 can be found in the table below.

MSP432P401R	**XBee**
Vcc	Vcc
GND	GND
3.2	Din

3.3	Dout

The MSP432 is configured to sample and send individual samples over the XBees. Essentially what it does is sample a 14-bit value from the microphone circuit through the ADC, and then store that value. Because the UART only allow for 8-bit transmission, we have to cut the the sampled value in half and send each half over the XBees individually. We cut the value into hiByte and loByte and send them individually. On the receiving end, hiByte and loByte are put back together.

The following list outlines our testing of XBee transmitting/receiving over UART on the MSP432.

1. MSP432 transmits known value to XCTU software on a laptop. The known value appears in the terminal of XCTU, confirming that it was successfully transmitted.
2. XCTU software on laptop transmits a known value to MSP432. Reception is verified in Code Composer studio by putting a breakpoint at the point where a signal gets received, and confirming that this is the known value.
3. Transmitting a known value from an MSP432 to MSP432. Reception is verified in Code Composer studio by putting a breakpoint at the point where a signal gets received, and confirming that this is the known value.

While we had successfully sampled the audio signal, transmitted the signal, and received it, we struggled to configure the DAC in Code Composer Studio. We could not get it to successfully output to the auxiliary jack. It was at this point that we turned to Energia because we believed we would be able to redevelop what we had already accomplished in Code Composer Studio in addition to configuring the DAC to output to the auxiliary jack.

Energia Development:

During the software development phase of the project we used the platform Energia to program. Energia is an open-source electronics prototyping platform that brings the Arduino and Wiring framework to the Texas Instruments LaunchPad. Our team split the code into two programs, the receiving or boat side and the transmitting or drone side.

The transmitting code took in the microphone values from analog input 15. These were then transmitted through serial UART connected to the Xbee.

```
const int MICAN = A15;    // MIC in

void setup() {
// put your setup code here, to run once:
Serial.begin(9600);
Serial1.begin(9600);// baud rate setting
}
void loop() {
Serial.print(MicVal); //debug values
Serial1.print(analogRead(MICAN));// send mic value
over serial

delay(1);// for testing
}
```

MICAN is the analog in pin 15 which the microphone output is hooked up too. Then in the setup loop we initialize the serial UART with a baud rate of 9600. The only reason Serial.begin is used was to debug the reading of analongRead.

The following code is from the receiving end of the project.

```
#include <SPI.h>

// SPI    SCK = 7
//        MISO = 14
```

```
//         MOSI = 15
const int cs = 8;    // SPI chip select
int testVal;
int DacValue;

void setup()
{
  Serial.begin(9600);
  Serial1.begin(9600);
  pinMode(cs, OUTPUT);
  SPI.begin();
}

void loop()
{
  if (Serial1.available()) {   // If there is data in
the buffer
    delay(1); // delay here for reliability
    DacValue = Serial1.read();
  }
    DacValue = ((DacValue-400)*2); //Convert the
readings into 3.3V
    Serial.print(DacValue); //Debugging purposes
    // Send the bytes out over SPI
    digitalWrite(cs, LOW); //Make chip select low to
send SPI
    SPI.transfer(DacValue >> 8); // Shift 8 most
significant bits over and
                                         // send them
first
    SPI.transfer(DacValue & 0xFF);  // Clear out the
MSB and send the LSB
    digitalWrite(cs, HIGH); //Make chip select high

    delay(10);
  }
```

In this code we again begin the serial UART with a consistant baud rate of 9600. We also begin the SPI so we can send data to the DAC. In the loop() we check to see if there is data in the UART buffer. If there is then read the values and set them to DacValue. Then we need to convert these values to 0-3.3V using the next line of code. Next, we set the chip select to low so we can send the data over SPI 8 bits at a time. In the SPI.transfer line we first shift the 8 most significant bits because only 8 bits can be transmitted at a time. Then we clear the 8 MSB and send the least significant bits. We then change the chip select to high so we can get the next reading.

Challenges

Our team faced numerous technical and nontechnical challenges throughout the duration of this project. The technical aspects related to XBee technology were especially challenging because none of our team members had worked with personal area networks before. Another challenge we faced was filtering out the sound of the propellers driving the quadcopter before the information is sent back to the boat. This will present a challenge as the noise of the copter will be constantly changing depending on the wind resistance against the flying copter.

The other challenge is keeping the weight of the payload as minimal as possible. Low end copters can only carry around 50 grams for a pay load, while high end copters can only carry a weight of about 150 grams. The current design for the payload will be 100-200 grams. This will limit our options of potential quadcopters, as it will have to be a higher end model in order to sustain the additional weight.

Configuring the DAC in Code Composer Studio proved to be a big challenge for our team. We spent about two weeks trying to figure that out, at which point we decided to move our development environment over to Energia. In the end, this proved to be an easier environment to work in, however it was essentially like starting over. We had to redo our configuration for the ADC/sampling circuit as well as the UART transmitting and receiving over XBees.

As far as non-technical challenges, we had a few parts stolen, including our XBee Pro boards, XBee programming boards, the auxiliary jack, and our breadboard. We had to order all new ones which set us back on our development schedule. Overall, the development was more challenging and took longer than we had originally anticipated. However, we are incredibly proud of what we were able to accomplish without funding or sponsorship in such a short amount of time.

Schedule

The team tried to stick to a general schedule to make sure our team met deadlines. During A term the team completed initial research and initial design of the project. We researched background information regarding whale tagging and implemented that research into our initial design. Furthermore, the group determined the setup of the system and picked out all parts for the payload. Parts were ordered at the end of the A term and arrived within the first week of B term. B and C term were dedicated to payload development and subsystems testing. We also did most of our programming development in C term, while finishing in D term. The group finalized the design in C term and continued development. Final testing was completed in D term.

Future Work

The team has come up with a few suggestions for future work that stem from the work that was completed this year. One suggestion for the design is a custom quadcopter, or the enhancement of an existing quadcopter, to fit the needs of our payload and the needs of marine biologists. This quadcopter would have to be able to fly carrying the payload, and also be able to stand up to a marine environment. Additional value adds could include the ability to take off and land in the ocean, or at least be able to survive a crash into the ocean.

Another idea is to create a type of tag deployment mechanism for the copter. This would allow marine biologists to remotely tag whales from a distance. This could potentially eliminate the need for them to go out on small skiffs and approach whales at a close distance. Instead, they could sit back from a distance and tag the whales remotely. There are two approaches to this: a mechanism that could fire a tag into the dorsal fin of the whale, or more realistically, a way to drive the copter over the whale and slap a suctioned tag down on its back. Both would be challenging projects, but could greatly benefit marine biologists and whale research as a whole.

Additionally, the group proposes that some research and project work be done in terms of extending battery life, and thus flight time, of quadcopters carrying a significant payload. This has proven to be a problem in the UAV industry, with flight time averaging around 10-15 minutes. In the context of our problem, 10-15 minutes is not a very long time. A good idea for future work would be looking into how to maximize flight time. If this is too difficult or cannot be done, then the design of an efficient battery charging station on the boat would be the next step. It currently takes multiple hours to recharge the quadcopter batteries, making it unrealistic to fly the copter, recharge it, and then send it back out for another flight. Even if the flight time is short, if a group could get the battery to recharge on the boat in a short enough amount of time, it would greatly help the marine biologists in their utilization of quadcopters for whale searching.

Conclusion

The team hopes to assist whale experts in the tracking and tagging of whales. As of now it is very difficult for researchers to locate whales efficiently. The team will overcome this issue with the creation of the Critter-Copter. The Critter-Copter will be an additional pair of eyes and ears over the vast ocean. Whale searching will be more efficient and less dangerous with our innovation.

To our current knowledge, drones have not yet been used for this purpose. Assuming the drone already has the capability to live stream video to a tablet, the team is proposing the following value add-ons to make it a more specific solution for marine biologists:

1st Base-line Goal: Add an acoustic sensor sub-system to the drone (to compliment camera)

2nd Base-line Goal: Implement drone localization sub-system using GPS technology

Reach Goal: Add sound localization using multiple microphones

With these goals met, the Critter-Copter will provide a new and useful capability to whale researchers. Furthermore, the Critter-Copter would not only be able to assist in just marine biology, but terrestrial animals as well.

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2. GP-735T
    a. https://www.sparkfun.com/products/13670
3. CME-1538 Omni-directional microphone
    a. http://www.digikey.com/product-detail/en/CME-1538-100LB/102-2190-ND/2364631
4. SHARP96 LCD Display
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5. MCP4921
    a. http://www.microchip.com/wwwproducts/Devices.aspx?product=MCP4921
6. Xbee-Pro Audio Transmitter/Receiver
    a. https://www.sparkfun.com/products/8742

Appendix A: Circuit Pictures

This appendix circuit pictures of our project and how we determined the calculations for the filter cut off frequency.

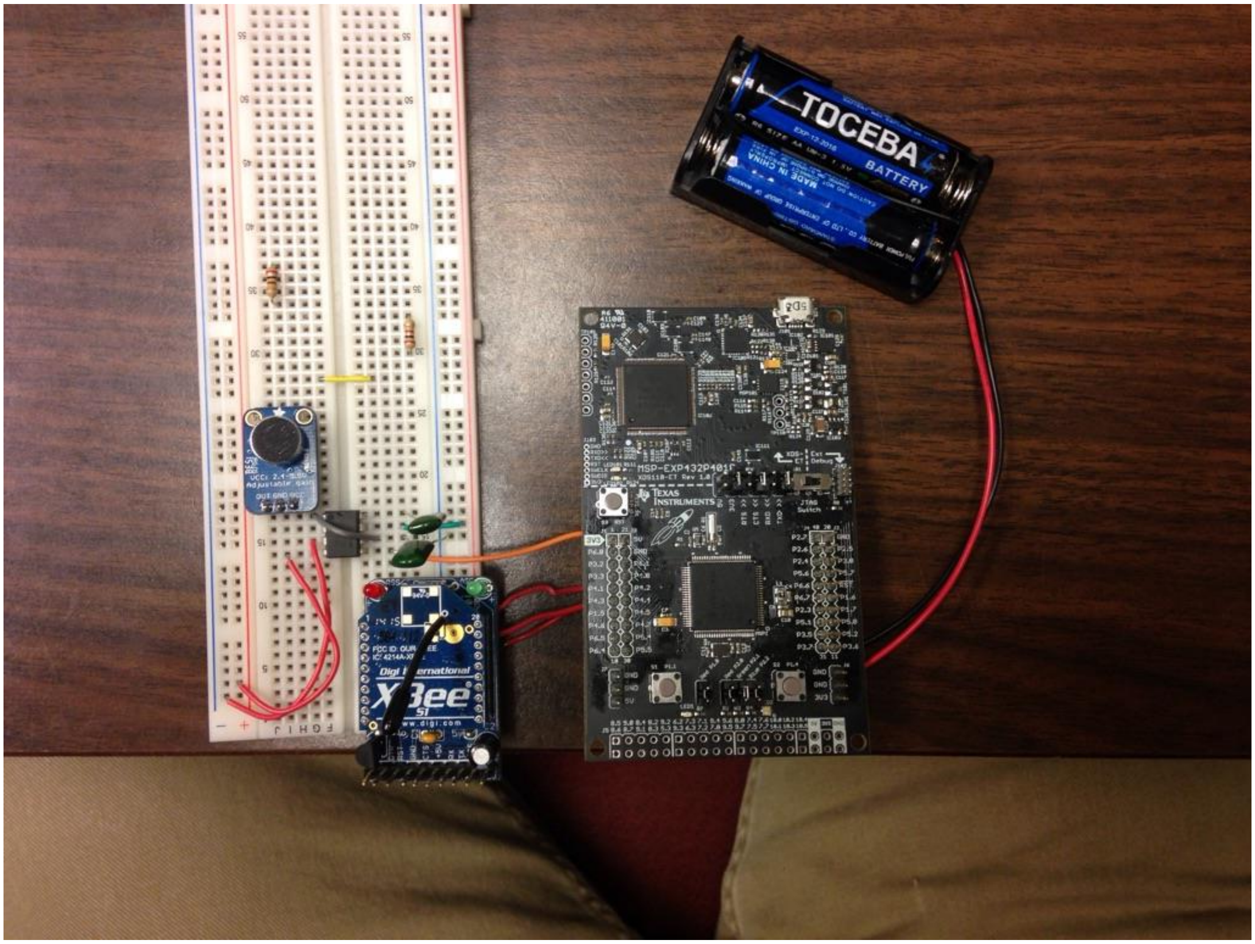


Figure 21: Drone side circuit

Figure 23 shows the circuit for the drone side subsystem. The MSP432 is powered by a battery pack, which also powers the microphone and Xbee. The output of the mic/amp component is connected to the filter which outputs the values into the MSP432. Then the Xbee will send the values via Serial UART.

We based our calculations off the datasheet example for a lowpass filter. The COM is connected to the OS which is then connected to ground through a .1uF capacitor. The 2nd pin is connected to the output of the MIC/AMP. The 3rd pin is ground and the 4th is VCC. Then the 5th pin is the output connected to the MSP432. Lastly, the CLK pin is connected to a 20pF capacitor.

The Formula for the cutoff frequency using the internal CLK is:

$F_{OSC}(kHz) = (K * 10^3)/C_{OSC}$; where C_{OSC} is in pF

So for this particular filter K = 31, and so the cutoff frequency was 1550kHz.

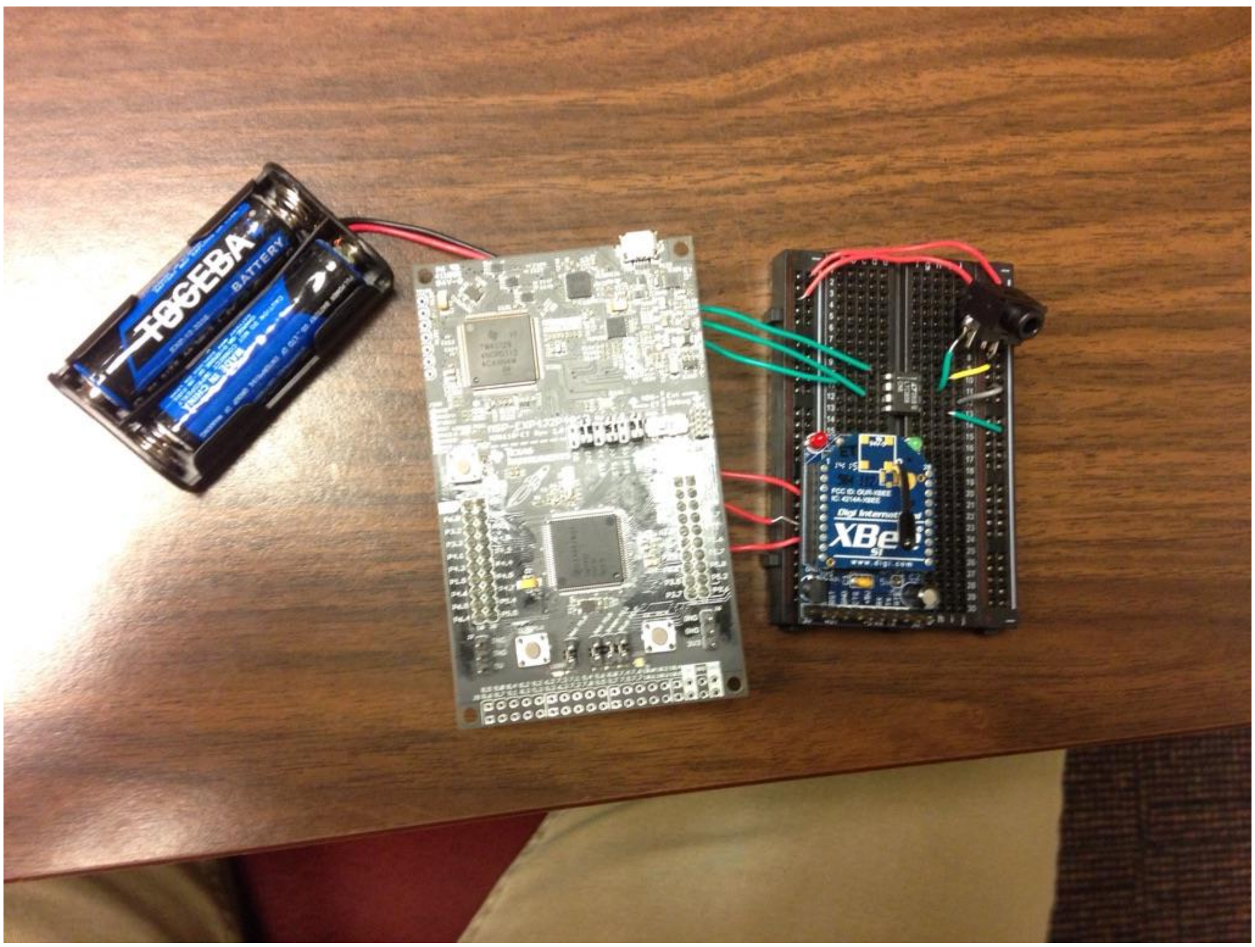


Figure 22: Boat side circuit

Figure 24 shows the circuit for the boat side subsystem of the team's project. Once again the system is powered by a 3V battery pack. The MSP432 is hooked up to the Xbee which is receiving the audio data. That data is then passed to the DAC via SPI. Once converted the audio signal can be heard from the aux Jack.

Appendix B: Datasheets

Note: Full datasheets can be found online.

LTC1658

14-Bit Rail-to-Rail Micropower DAC in MSOP

FEATURES

- 14-Bit Resolution
- **8-Lead MSOP Package**
- **Buffered True Rail-to-Rail Voltage Output**
- 3V or 5V Single Supply Operation
- Very Low Power: $I_{CC(TYP)} = 270\mu A$
- Power-On Reset
- 3-Wire Cascadable Serial Interface is Compatible with SPI and MICROWIRE™
- **Maximum DNL Error: 1LSB**
- Low Cost

APPLICATIONS

- Digital Calibration
- Industrial Process Control
- Automatic Test Equipment
- Cellular Telephones

DESCRIPTION

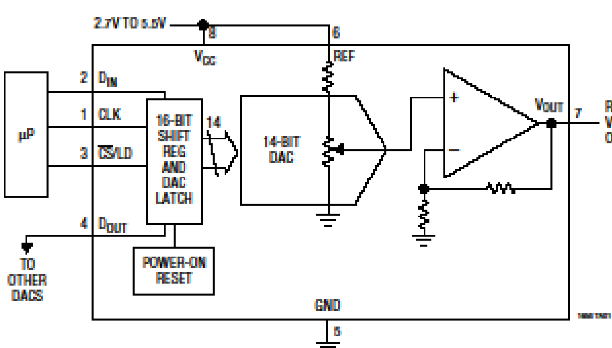
The LTC®1658 is a single supply, rail-to-rail voltage output, 14-bit digital-to-analog converter (DAC) in an 8-lead MSOP package. It includes an output buffer amplifier and an easy-to-use 3-wire cascadable serial interface.

The LTC1658 output swings from 0V to V_{REF}. The REF pin can be tied to V_{CC} for rail-to-rail output swing. The LTC1658 operates from a single 2.7V to 5.5V supply. The typical power supply current is 270µA.

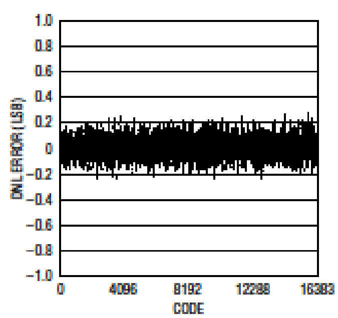
The low power supply current makes the LTC1658 ideal for battery-powered applications. The space saving MSOP provides the smallest 14-bit DAC system available.

TYPICAL APPLICATION

Functional Block Diagram: 14-Bit Rail-to-Rail DAC



Differential Nonlinearity vs Input Code



DIGI

EMBEDDED RF MODULES FOR OEMS

XBEE® 802.15.4 RF MODULES

Low-cost, easy-to-deploy modules provide critical end-point connectivity to devices and sensors

XBee 802.15.4 RF modules provide OEMs with a common footprint shared by multiple platforms, including multipoint and ZigBee/Mesh topologies, and both 2.4 GHz and 900 MHz solutions. OEMs deploying the XBee can substitute one XBee for another, depending upon dynamic application needs, with minimal development, reduced risk and shorter time-to-market.

XBee 802.15.4 RF modules are ideal for applications requiring low latency and predictable communication timing. Providing quick, robust communication in point-to-point, peer-to-peer, and multipoint/star configurations, XBee 802.15.4 products enable robust end-point connectivity with ease. Whether deployed as a pure cable replacement for simple serial communication, or as part of a more complex hub-and-spoke network of sensors, XBee 802.15.4 RF modules maximize performance and ease of development.

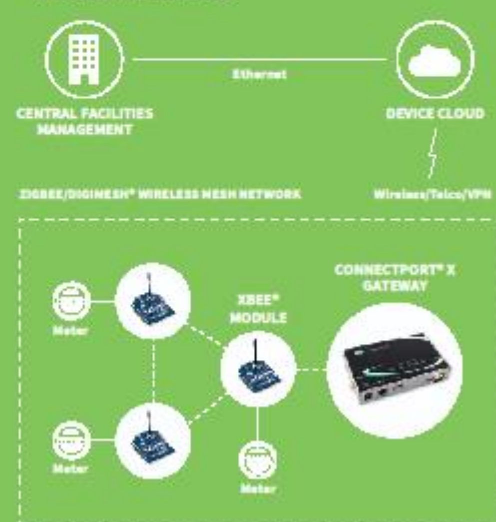
XBee 802.15.4 modules seamlessly interface with compatible gateways, device adapters and range extenders, providing developers with true beyond-the-horizon connectivity.

BENEFITS

- Point-to-multipoint network topology
- 2.4 GHz for worldwide deployment
- 900 MHz for long-range deployment
- Fully interoperable with other other Digi networking products, including gateways, device adapters and range extenders
- Common XBee footprint for a variety of RF modules
- Low-power sleep modes
- Multiple antenna options
- Industrial temperature rating (-40° C to 85° C)

RELATED PRODUCTS

APPLICATION EXAMPLE



19-4788; Rev 1; 6/99

MAXIM

8th-Order, Lowpass, Bessel, Switched-Capacitor Filters

MAX7401/MAX7405

General Description

The MAX7401/MAX7405 8th-order, lowpass, Bessel, switched-capacitor filters (SCFs) operate from a single +5V (MAX7401) or +3V (MAX7405) supply. These devices draw only 2mA of supply current and allow corner frequencies from 1Hz to 5kHz, making them ideal for low-power post-DAC filtering and anti-aliasing applications. They feature a shutdown mode that reduces supply current to 0.2µA.

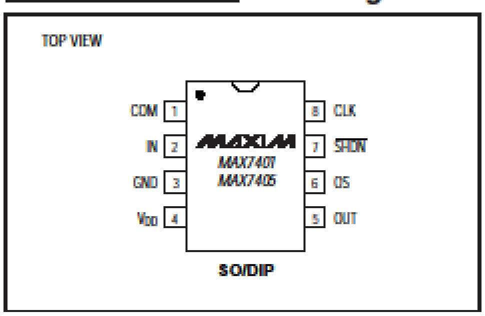
Two clocking options are available on these devices: self-clocking (through the use of an external capacitor) or external clocking for tighter corner-frequency control. An offset adjust pin allows for adjustment of the DC output level.

The MAX7401/MAX7405 Bessel filters provide low overshoot and fast settling. Their fixed response simplifies the design task to selecting a clock frequency.

Applications

ADC Anti-Aliasing
Post-DAC Filtering
Air-Bag Electronics
CT2 Base Stations
Speech Processing

Pin Configuration



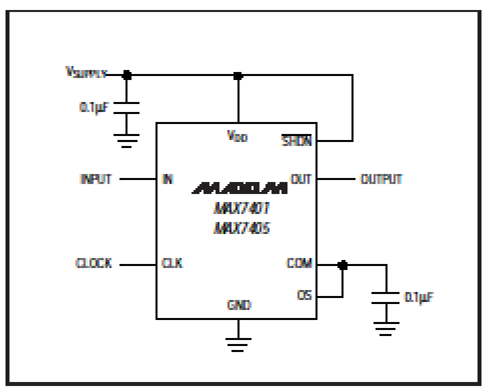
Features

- **8th-Order, Lowpass Bessel Filters**
- **Low Noise and Distortion: -82dB THD + Noise**
- **Clock-Tunable Corner Frequency (1Hz to 5kHz)**
- **100:1 Clock-to-Corner Ratio**
- **Single-Supply Operation**
  +5V (MAX7401)
  +3V (MAX7405)
- **Low Power**
  2mA (Operating Mode)
  0.2µA (Shutdown Mode)
- **Available in 8-Pin SO/DIP Packages**
- **Low Output Offset: ±5mV**

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX7401CSA	0°C to +70°C	8 SO
MAX7401CPA	0°C to +70°C	8 Plastic DIP
MAX7401ESA	-40°C to +85°C	8 SO
MAX7401EPA	-40°C to +85°C	8 Plastic DIP
MAX7405CSA	0°C to +70°C	8 SO
MAX7405CPA	0°C to +70°C	8 Plastic DIP
MAX7405ESA	-40°C to +85°C	8 SO
MAX7405EPA	-40°C to +85°C	8 Plastic DIP

Typical Operating Circuit



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